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DDMRP: presentation of a new solution of stock management and master production scheduling

MEMÒRIA

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Abstract

Demand Driven Material Requirements Planning (DDMRP) is a new solution of stock management and master production scheduling invented in the years 2010s. It is constructed on the main principles of Material Requirements Planning (MRP), Distribution Requirements Planning (DRP), Lean Manufacturing, Theory of Constraint (TOC) and Six Sigma. It is based on four actions: position, protect, pull and adapt. Position the buffer at the strategic points, protect them with stock and decoupled lead time, pull the demand when the buffers need it and adapt to the evolution of the environment. DDMRP allows the purchase team to prioritize their work thanks to a three color-code management (green, yellow and red) based on a net flow equation that includes the stock on-hand, the supplies on-going and the future spikes of demand that might harm the buffer. The objective of this master thesis is to present the method, describe the five steps of implementation and discuss its benefits and limitations.

Keywords: DDMRP, stock management, production scheduling, visual management, VUCA.

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1. Glossary

Abbreviation	Signification
ADU	Average Daily Usage
BOM	Bill Of Materials
CIPE	Centre International de la Pédagogie d'Entreprise
ConWIP	Constant Work In Progress
DAF	Demand Adjustment Factor
DDI	Demand Driven Institute
DDMRP	Demand Driven Materiel Requirements Planning
DES	Discrete Events Simulation
DLT	Decoupled Lead Time
DPM	Defect Per Million
DRP	Distribution Requirements Planning
EOQ	Economic Order Quantity
ERP	Enterprise Resources Planning
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JIT	Just In Time
KPI	Key Performance Indicator
LTF	Lead Time Factor
MOQ	Minimum Order Quantity
MPS	Mater Production Scheduling
MRP	Material Requirements Planning
MRPII	Manufacturing Resources Planning
OTD	On Time Delivery
VF	Variability Factor
VUCA	Volatility, Uncertainty, Complexity and Ambiguity
WC	Working Capital
WIP	Work In Progress

Figure 1 - Glossary used in the report [Own source]

2. Preface

This master thesis has the finality of validating my final year in the master's degree in Supply Chain, Transport and Mobility Management of the ETSEIB school. This will also allow me to complete my double diploma with the French school CentraleSupélec and my years of studying.

During this second period of the academic year 2019/2020, I am also currently enrolled in an internship of 6 months in a consulting firm, Citwell Consulting, specialized in logistic, supply chain and change management. This firm is one of the few pure-player in supply chain who joined the Demand Driven Institute (DDI), a private group in charge of the construction and improvement of the solution Demand Driven Material Requirements Planning (DDMRP).

Because the consulting firm where I am doing my curricular practice led and is leading DDMRP projects in various French companies, I found interesting to make a research project to explain the methodology of this new solution of stock management and what is different of the other solutions.

The system is quite recent, from the years 2010s and there is still a lot to study and improve on it. In fact, I had not heard this name “DDMRP”, before joining the firm, even after two years passed in a master specialized in those subjects. Those points brought my curiosity to the point where I decided to make it my master thesis.

3. Introduction

In the second part of the twentieth century, most of the improvements in the industries were focused on the optimization of the lines of production. But, as the systems were becoming more complex (increase of the number of suppliers, globalization of the distribution networks…), the need of having a well-adjusted stock increased likewise.

However, most of the systems still used in the industry for stock management did not evolved in the last fifty years while the world was deeply changed in its interaction with the industries. The term VUCA is now used to describe the environment the industries must adapt to. V for volatility, as the product cycle lifespan has shrunk. U for uncertainty, the forecasting of the future becoming more complex with the increase in the number of available information and rapid change of the market. C for complexity, with continuously more external and internal factors to consider before taking a decision. And A for ambiguity, as the past and present events can be difficult to understand and inject in the current model [1], [2].

A new solution, the Demand Driven Material Requirements Planning, emerged in the beginning of the 2010s, created by Carol Ptak and Chad Smith, to propose a new way to deal with those new factors and improve the management of stock in the industries.

In this master thesis report, the DDMRP method is introduced and explained. First, the two main types of solutions in stock management are presented. Then, the DDMRP solution is described: how was it constructed and what can be the expected results. A concrete example is presented to describe its implementation and to comment the differences with other methods. After that, the drawbacks of DDMRP and what could be improved in the future are discussed. Then, a state of art is performed to categorize the level of research done on this method and to highlight the results and discussion of the already-existing papers. At the end, an environment impact study and an evaluation of the costs and workload linked to a DDMRP implementation are done.

3.1. Project's objective

As this method is quite new and little known, the objective of this master thesis is to describe, highlight the benefits and discuss the new solution in stock management called Demand Driven Material Requirements Planning.

In order to do that, the five steps of implementation will be detailed to give a full tutorial guide to the readers. An invented example will be constructed and used, step by step, to help the comprehension. The goal is that this report could be used for companies or researchers to guide them through a first implementation of the DDMRP method.

3.2. Scope of the project

The project will be focused on the presentation of the Demand Driven for stock management method, called DDMRP and will not discuss the other new options which have appeared in the last decades (like ConWIP – Constant Work In Progress - for example).

In addition, this master thesis will only focus on DDMRP, even if the Demand Driven Institute has created a broader system, called Demand Driven Adaptive Enterprise, which will be only briefly presented.

Finally, a concrete example of simulation of implementation of DDMRP will be held through data from a French company. For confidentiality reasons, the name of the company will not be given.

4. Actual solutions in stock management

There are a lot of solutions for production planning and stock management in the industry. However, they can be sorted in two main types of solution: push-flow and pull-flow. The objective of this chapter is to briefly describe those types to understand what are their defects that led to the creation of the DDMRP solution, that is presented as a hybrid method taking the efficient tools of both types.

4.1. Push-flow solutions

Push-flow solutions, like MRP (Material Requirements Planning) were conceived in the years 1960s [3], [4], while the demand was well known with low variability. The goal was then to optimize the costs of stock management in deterministic environments. This led to the EOQ (Economic Order Quantity) management system that gives the order quantity (hence also the frequency of order) that minimizes the operating costs.

Simpler push-flow solutions consist in a Min/Max condition where when the stock decreases and goes under the minimum quantity, an order is launched to replenish the stock at the maximum level. Those thresholds are calculated with the lead time of the supplier (or the lead times of the fabrication process or of the carrier, depending on the situation) and the average usage of the reference.

All those solutions are based on two principles:

- The stock will be replenished as late as possible: to minimize the holding costs, the MRP will order quantities at the latest time;
- The environment is deterministic: the demand is always known and stable and the lead times are fixed.

Those assumptions could, in the environment VUCA that was previously described, create a lot of shortage in the stock, because the lead times can increase in case of issues during the transport, the quality control, the production or because the demand can be highly variable and uncertain. Hence, the solution was to implement safety stocks for each reference. Therefore, the holding costs increase, and the management of the safety stocks is more difficult as there is no global algorithms or rules to follow.

The MRP solution has evolved in the MRPII (Manufacturing Resources Planning) in the 1980s and later in the ERP (Enterprise Resource Planning) in the 1990s [5]. MRPII takes the principle of the MRP but add the constraints of resources (material, human and industrial tools). It allows the companies to construct their MPS (Master Production Scheduling) and Capacity planning that gives what must be produced and when within the actual capacities of the factories and suppliers. ERP takes the integration further by including the other functions (sales, marketing, accounting…) of a company to deal with all the processes and data that can be stored, interpreted and managed for business activities.

4.2. Pull-flow solutions

At the opposite of the push-flow solutions, where the orders of replenishment are driven by the physical level of stock, there are the pull-flow solutions. These methods are designed to adapt the production to the real customer demand and the management of the working capital, especially the WIP (Work in Progress: quantity of product currently in the fabrication and/or distribution process).

Those solutions, driven by the JIT policy (Just In Time) were developed in the Toyota Production System in the 1970s and have evolved more generally into what is now called Lean Manufacturing [4].

To implement this type of solutions, Kanban cards are often used (physical and/or through an information flow) to help the management of the pull-flow theory. Any step in the supply chain (replenishment from a supplier, operation on a raw-material or semi-finished product, sending stock to a wholesaler…) is only started when the Kanban is received, even if all the resources were available before. This strategy allows companies to focus on what the demand really is and eliminates the waste (muda) [6] of over-production and high level of stocks.

But those solutions are extremely sensitive to the variation of demand, as they operate in tense flow, and any spike could result on a shortage or a backorder in the systems. Hence, while it was firstly constructed to be more agile and adaptive for the companies, they might lose in agility and become more fragile in a VUCA environment. That's why those solutions are often used only in strategic parts of the supply chain while other parts can be managed with more traditional push-flow system like MRP. The strategic criteria to decide to implement Kanban/Lean solutions or not are, for examples:

- If the pieces/materials used are expensive: a company will try to minimize the WIP stock of an expensive component as it would impact its working capital. Furthermore, as the stock must be insured and could be damaged or became obsolete, owning stock has a recurrent cost that is defined around 10 to 30 percent of the buying cost;

- If the lead times are short and consistent: if the lead time is important, because a supplier is on the other side of the globe for example, the strategy will be oriented to a push flow solution, as the goal will be to optimize the cost of transportation disregarding the one-piece flow option. In addition, in case of variability, it is better to own a safety stock to minimize the shortage risk;
- If the pieces/materials used are specific and/or customized: a company proposing customization for its product will try to postpone the more possible the decoupling point where the products become specific. The strategy applied could be to push the flow till the decoupling operation then to apply a lean process with Kanban card and only product when the demand arrives.

That also give a first level of decision between the choices of a make to stock system (push-flow) and a make to order (pull-flow) system.

The needs of a new type of solution for stock management and production control has been highlighted by Ptak and Smith in 2011 and they started working on a new type of system: The Demand Driven MRP [7].

5. Demand Driven Material Requirements Planning

The objective is here to present, define and describe the Demand Driven Material Requirements planning (DDMRP) method which is becoming more present in the industry objectives.

5.1. Origins and construction

Carol Ptak and Chad Smith arrived at the conclusion in their book from 2016 [7] that using push flow solution (MRP) or Lean (Kanban) both conducts to unsatisfying results. The systems do not adapt very well to the variability which leads for example to the Bullwhip Effect: a small variability in a part of the chain is going to be disrupted and amplified while going upstream in the distribution and production chains. As it is represented in the figure 2, four types of variability are possible and are going to disturb the well-being of the system and decrease its performance:

- The variability from suppliers: an irregular and/or significant lead time or an important MOQ (Minimum Order Quantity) can disrupt the production needs and oblige producers to overstock their factories;
- The variability from demand: in a VUCA environment, the demand can quickly change. In addition, for the reasons of the variability from suppliers, demand tends to arrive in aggregated batch which hides the level of the real demand;
- The variability from operative systems and management: for technical reasons and cost optimization, the production lines can create variability and lower the performance of the global system by trying to optimize their own;
- The variability from executive decisions: for policy reasons or change in the high management, variability can be created by changing strategic decisions in the companies which will be applied at an operative level.

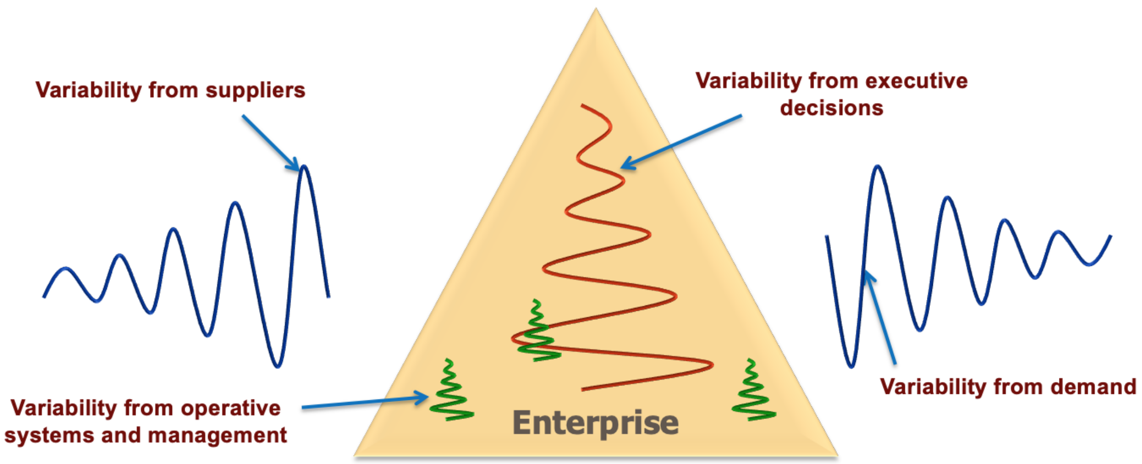


Figure 2 - Different origins of variability [8]

From that analyze, they created a new type of production planning and stock management method called Demand Driven MRP that is based on the 6 pillars illustrated on the figure 3:

- Material Requirements Planning (MRP): which was described in the previous part;
- Distribution Requirements planning (DRP): a method for companies to optimize and manage the distribution of their products in their points of distribution (wholesalers, crossdocking warehouses, shops…) with the stock on hand and the demand as principal inputs;
- Lean: the pull-flow philosophy which was also described before;
- Theory of constraints: a management system based on the key idea that the weakest link on the chain is a constraint and define the rest of the chain. Hence, the goal of the method is to identify, protect and pilot (and improve if possible) the link;
- Six Sigma: a list of techniques to improve the quality of a company processes based on the objective of 99,9997% products without defects (which leads to a score of 3 DPM: 3 defects per each millions of products);
- Innovation: to this set of methods they added some innovations to construct the DDMRP method as they intended: the decisional buffers, the net flow equation, the adaptive factors…

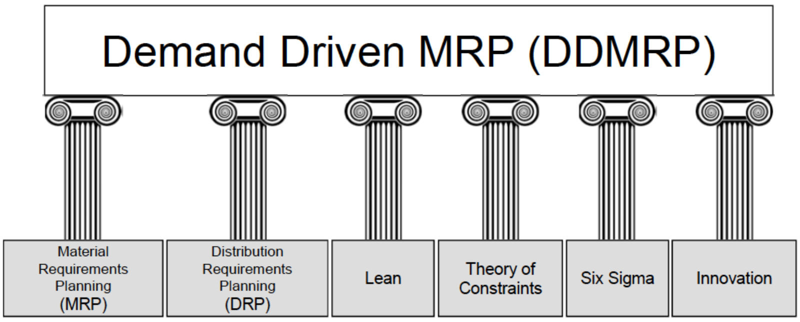


Figure 3 - The 6 pillars of DDMRP [7]

5.2. Implementation and piloting

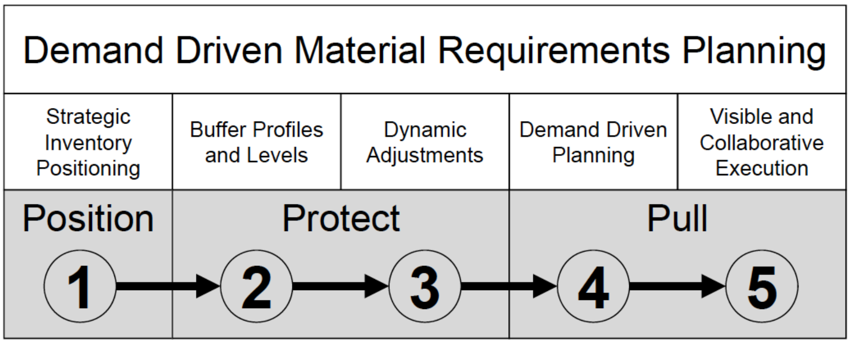
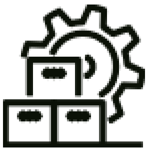


Figure 4 - The 5 steps of DDMRP [7]

The DDMRP system is based on three phases and 5 steps (resumed in the figure 4). First phase is about positioning the buffers in the supply chain. Second phase is about setting the necessary protection on those buffers. Third and last phase is the operational part, pulling the product when needed using the DDMRP criteria.

__Example:__ The description will be helped by an invented example of a piece called “material A” with the parameters specified in figure 5 .



Material A

Working day per year	220 d
Annual demand	2640 u

Figure 5 - Presentation of material A [Own source]

5.2.1. Strategic inventory positioning

DDMRP is based on setting inventory stock (which are called buffers in the method) across the supply chain to reduce the variability by cutting it in smaller parts with protected buffers at the extremity. Before positioning the buffers (as seen on the figure 6), the lead time of the system is the sum of all lead times (from supplier to the production, in the production lines and from production to the distribution centers) and the variability is not constrained to a part of the chain.

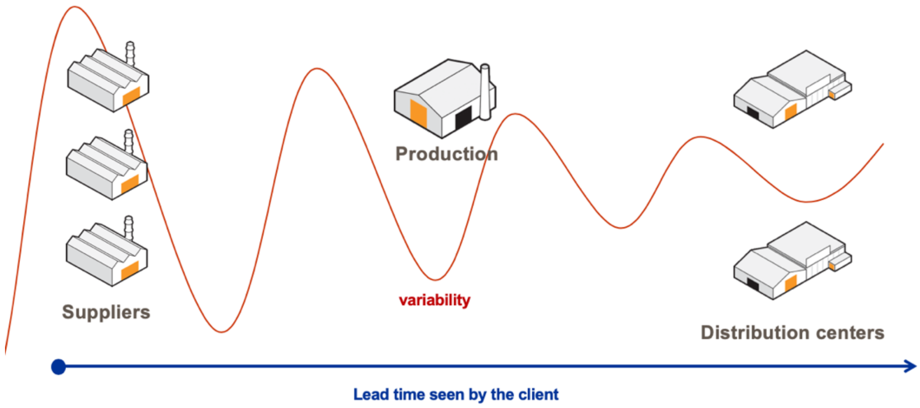


Figure 6 - Lead time and variability without buffer [Own source]

The goal is then to position buffers at strategic points in the supply chain to reduce what is called the DLT (Decoupled Lead Time) which is the maximal lead time of the unprotected chain between two buffers. With this strategy, the perceived lead time by the clients (external and internal) is now resumed to this variable, the DLT. Furthermore, the variability is reduced because of the buffers that are here to absorb the pikes and bullwhip effect going on the production and distribution chains. The new solution can be observed on the figure 7.

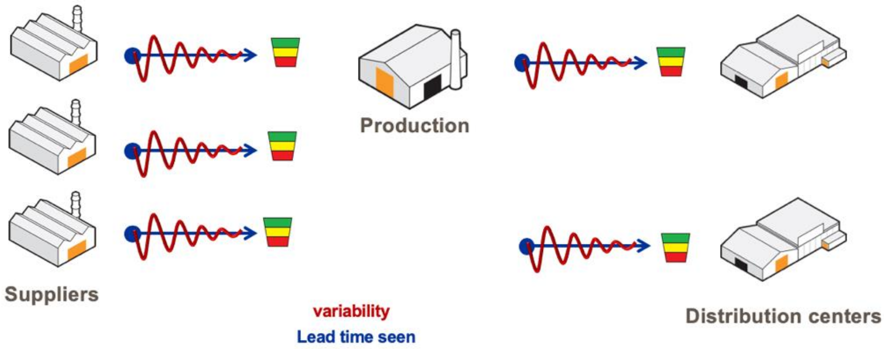


Figure 7 - Decoupled lead time and controlled variability with buffers [Own source]

One solution could be to set buffers at every distinct link of the supply chain: for every component send by supplier, after every operation on the semi-finished products in the production/assembly lines and at every step in the distribution network. But that would be counterproductive as each buffer means an increase of the global stock level, hence an increase of the cost of maintenance. Moreover, some operations are not critical because they are not on the critical path or because there is no variability on the quality and/or lead time of the link.

That is why it is important to identify the important steps to cover with buffers. There is no process completely clear on which buffer should be elected or not, but Ptak and Smith [7] created criteria for positioning decision:

- The lead time expected by the clients: if it appears that the clients are not really demanding regarding the lead time, there is no direct interest to position a buffer at the end of the chain;
- The opportunity lead time of the market: in some cases, in a market in expansion with a lot of competition and low fidelity, every small delay in the supply chain can create an important loss of market;
- Visibility horizon of demand: if the forecast is not reliable or not possible at a satisfying horizon, it is interesting to position a buffer before that to absorb the possible variability of the demand;
- The external variability: some operation can deal with factors external to the company (international policy, climate environment, social factor…) that could lead to a variability of its efficiency. Therfore, a buffer could be placed after it to protect this case and keep the performance of the system;
- The protection of critical operations: some stops in critical operations can directly impact all the supply chain, it is hence important to protect them by positioning buffers before and/or after them (criteria derived from the theory of constraints).

At the end of this first step, the output is the list of operations and places that need a buffer to efficiently protect the supply chain from the variability. Because there are no binary rules to position or not a buffer, it is important to remind that it is not a definitive list and that after the implementation, the number and position of the buffers can be modified to improve the reaction of the method.

5.2.2. Buffer profiles and levels

In DDMRP, a buffer is defined by a stack pile including three main zones: the green, yellow and red zones and is represented like in the figure 8. The goal of this representation is to simplify the decision making with visual management. The main rule is: when the net flow equation goes under the top of the yellow zone, there is an order passed (replenishment or production order) to return the net flow equation to the top of the green zone. In other terms, the green zone represents the average frequency of the orders and their lot size, the yellow zone represents the on-going orders waiting to arrive and the red zone is the safety zone, which duty is to absorb the variability spikes.

Figure 8 - The 3 zones of a DDMRP buffer [Own source]

To define what is the net flow equation and construct the buffer zones, the following variables and factors are used:

- ADU (Average Daily Usage): it gives the average consumption of the considered product to primarily size the buffer. Two methods can be use at that point: it can be a static variable defined by exploring the past data from the company or the available forecast, in that case the buffer will be called “static”. However, the buffer can be “dynamic” by recalculating every day its ADU by measuring the new mean consumption on a defined horizon (in the past and in the future);

- DLT (Decoupled Lead Time): the largest lead time of the unprotected chain between two buffers, as it was explained in the previous part;
- MOQ (Minimum Quantity Order): it is a defining variable because if an operation or a supplier has an important MOQ, it will obligate the buffer to take it into account in the decision on when the stock must be reordered;
- LTF (Lead Time Factor): numerical variable between 0 and 1, that has to be decided by the company to in function of the relative duration of the lead time (short, medium, long…);
- VF (Variability Factor), like the precedent factor, it has to be decided in function of the relative variability of the buffer (low, medium, high…).

The two factors, Lead time and Variability, can be left at the medium value of 0,5 when there is no particular information to balance the buffer on a side or another.

Once the variables and factors are defined, the size of each zones can be measured with the following equations:

$$Green\ zone = Max\{ADU * DLT * LTF; MOQ\}$$

$$Yellow\ zone = ADU * DLT$$

$$Red\ zone = DLT * ADU * FLT + DLT * ADU * LTF * VF$$

Two points has to be highlighted at this moment:

- It is important to calculate the top of each zone after measuring the sizes of the zones. Indeed, it is those levels that will be used in the planning and executing parts. The calculation is easy:

$$Top\ of\ green = Top\ of\ yellow + Green\ zone$$

$$Top\ of\ yellow = Top\ of\ red + Yellow\ zone$$

$$Top\ of\ red = Red\ zone$$

- The red zone can be subdivided in two parts: the red base and the red security (which is the red base times the variability factor). The distinction can be useful in the execution part.

Material A: parameters	
working days	220 d
Annual demand	2 640 u
ADU	12 u/d
DLT	3 d
MOQ	10 u
LTF	0,5
VF	0,5

Material A: buffer	
Green zone	=MAX(12*3*0,4;10) = 18
Yellow zone	=12*3 = 36
Red zone	=12*3*0,5+12*3*0,5*0,5 = 18 + 9 = 27

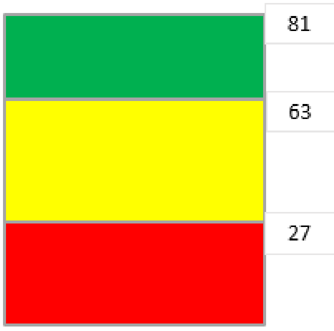


Figure 9 - Sizing of the material A Buffer [Own source]

Example: For the material A (described in figure 9), the ADU is easily measurable by dividing the annual demand by the number of working days per year. This buffer is static, because it does not consider a dynamic value for the Average Daily Usage of the material. The DLT and MOQ have been set to random value for this example. The variability and lead time factors have been set to their medium value as there is no relative information to the other components. The table gives the size of each zone and the global size of the buffer with the top of each zone.

It is important to note that DDMRP can work without taking into account the forecast by only considering the dynamic past ADU (or giving it a fixed value). Depending on the company situation and buffer situation, it can be useful or not to include a part of forecast in the ADU calculation. Here again, it is an on-field solution that has to be adapted and improved after implementation to obtain better results.

5.2.3. Dynamic adjustments

Once the sizing of the buffers is done, a last preparation step allows the system to be more efficient with seasonality and the product's cycle of life: the dynamic adjustments. Two scenarios that could happen to a buffer are taken into account:

- The evolution in a product lifecycle: some finished-goods or components can change and evolve with the evolution of the market and the company strategy and DDMRP has taken that into account. Hence, it is possible to apply a factor to simulate the ramp-down or ramp-up of a product in the future, while the actual ADU has not yet taken it in consideration at the moment. This is useful when the stock's management is done without access to forecast but with knowledge of the company evolution;

- The seasonality of a product: in some industries, the consumption of goods is linked to the time of the year. If this condition is not anticipated, it could lead to a shortage or an overstock in the warehouses for a long time. That is why DDMRP has given the opportunity for the buffer size to evolve during the period of the year.

Those two scenarios are considered with a numerical variable called DAF (Demand Adjustment Factor) that needs to be indicated on a timeline to increase or decrease the buffer size depending on the situation of the considered moment.

5.2.4. Demand Driven planning

One of the strengths of the DDMRP is its ability to combine the planification and the execution for the purchase and supply team, based on a visual tool to allow a quick and concrete view of the real-time situation. The fourth step is the planification order: now that the buffer is built, it can be checked every day to decide if it must be replenished or not.

To determine if a new order has to be launched, the net flow equation is analyzed. This equation is the result of the sum of the actual stock on-hand and the supplies on-order minus the qualified demand.

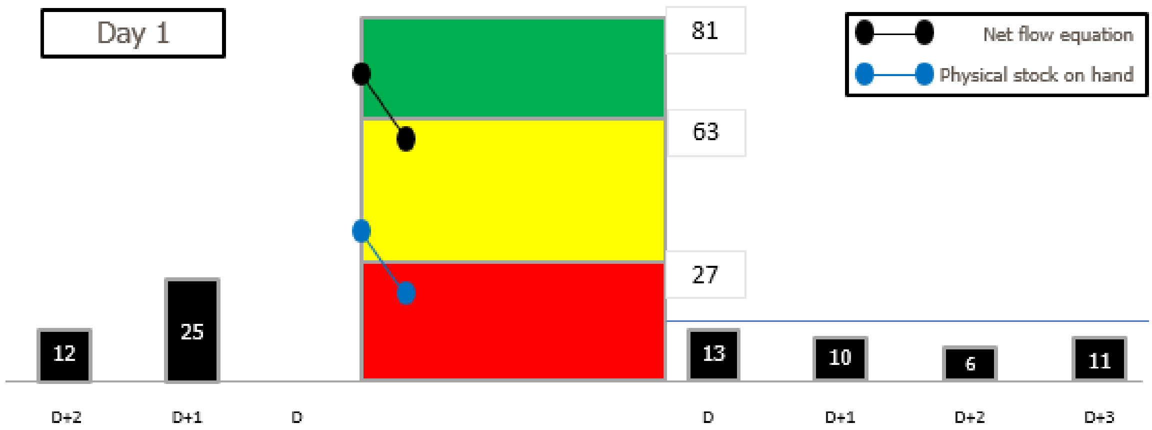
$$Net\ flow\ equation = Stock\ on\ hand + Supplies\ on\ order - Qualified\ demand$$

This equation contains a different type of temporality for each of its components:

- The stock on hand is determined at the moment and is equal to the physical stock available at the buffer;
- The supplies on order are identified on a period usually equal to the decoupled lead time. That means that when a new order is passed, the stock on hand does not change because it has to wait the DLT to receive the material but the supplies on order level directly increases of the quantity of the order;
- The qualified demand is one on the main innovation of DDMRP and consists in considering the spikes of demand where the visibility allows it (generally on a period equal to the DLT). The usual rule is to say that a daily demand is a qualified demand if it represents more of the safety of the red zone (close to half the size of the global red zone). In addition to that, the daily demand is added to form the qualified demand.

Every day, the net flow equation can be calculated for each buffer and the rule is to pass an order to get back at the top of the green zone as soon as the net flow equation goes under the top of the yellow zone. Therefore, the two main steps are: calculate the value of the net flow equation and determine the number of units to reorder.

Example: The assumption for the material A is that on first day of the simulation, it has a stock on hand of 35 units. In addition, there are two on-going supplies order (25 in 1 day and 12 in 2 days). The buffer has a visibility of 3 days on the ongoing demand (and for the simulation here is the random values of the daily demand in the following days: 13 ; 10 ; 6 ; 11 ; 24 ; 7 ; 8).



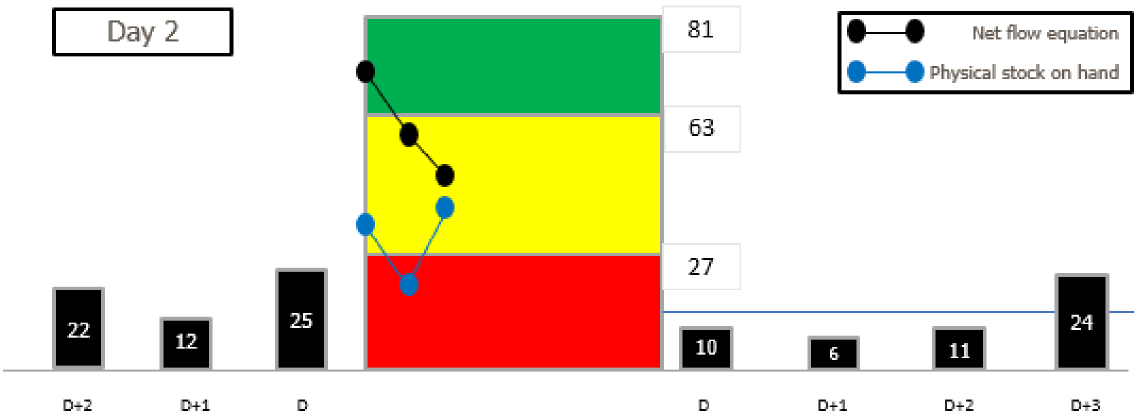
1	Physical stock on hand	35
2	Supplies on order	37
3	Qualified demand	13

4	Net flow equation	59
5	Quantity to reorder	22
6	Physical stock end of day	22

Figure 10 - Day 1 of the simulation on material A [Own source]

Each day, the DDMRP method allows the purchase team to compute the main indicators to decide if the material A must be reordered or not. There are six key values to evaluate: the stock on hand at the beginning, the supplies on order, the qualified demand, the net flow equation, the quantity to reorder and the stock on hand at the end of the day. For the example, the initial stock is 35, and the initial net flow equation is $35 + 37 = 72$ (initial stock + supplies on order).

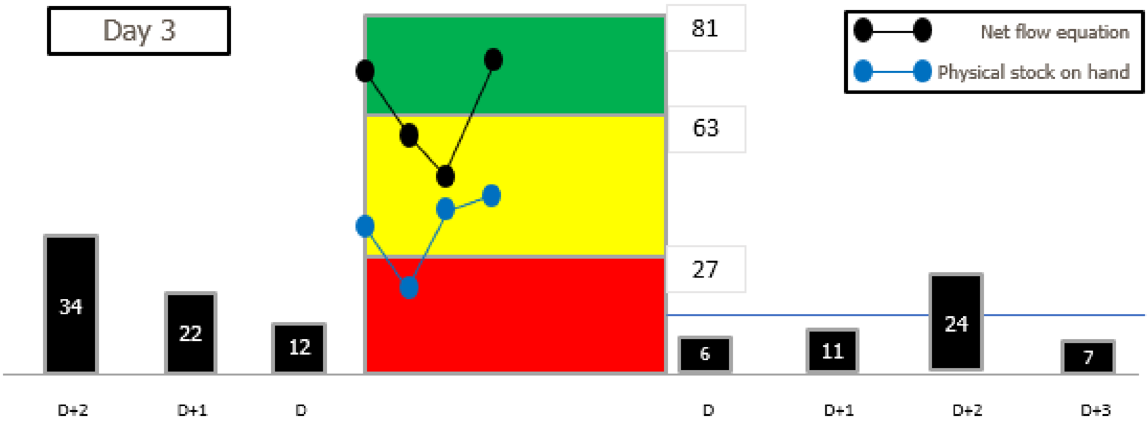
On day 1 (represented in figure 10), there are $12 + 25 = 37$ supplies on order and the qualified demand is 13, which is only the demand's day as there is no detectable spike of demand in the horizon. Therefore, the net flow equation is equal to $35 + 37 - 13 = 59$. The net flow equation is below the top of the yellow zone (63) so an order must be passed to the top of the green zone (81): the quantity to reorder is $81 - 59 = 22$. At the end of the day, the physical stock is at $35 - 13 = 22$: there are no supplies delivered today so it is only the subtraction of the demand on the stock.



1	Physical stock on hand	22	4	Net flow equation	47
2	Supplies on order	59	5	Quantity to reorder	34
3	Qualified demand	34	6	Physical stock end of day	37

Figure 11 - Day 2 of the simulation on material A [Own source]

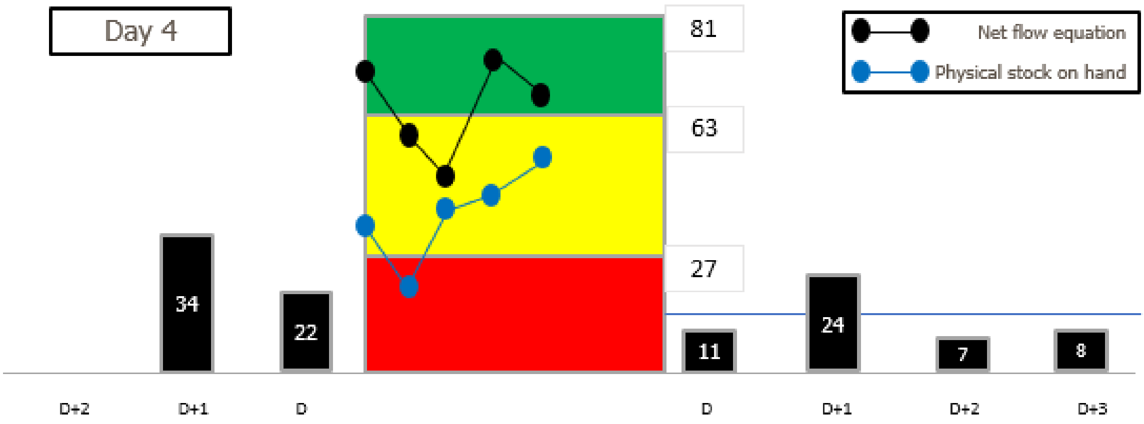
On day 2 (figure 11), the initial stock is 22 and the supplies on order have increased with the reorder of the day 1 and are now equal to $22 + 12 + 25 = 59$. The buffer can detect a spike of demand higher than its security red zone in 3 days and is going to take it into account to anticipate and mitigate its effects. Hence, the qualified demand is $10 + 24 = 34$, the demand of the day and the demand spike. Therefore, on day 2, the net flow equation is equal to $22 + 59 - 34 = 47$. The net flow equation is still below the top of the yellow zone (63) so an order must be passed to the top of the green zone (81): the quantity to reorder is $81 - 47 = 34$. At the end of the day, the physical stock is equal to the initial stock plus the inbound flow of material minus the consumption of the day, which means: $22 + 25 - 10 = 37$. The fact that the net flow equation stayed on the yellow zone highlights the anticipation of the buffer to absorb the demand spike. Two close reorders have been passed in the objective to minimize the risks of shortages.



1	Physical stock on hand	37	4	Net flow equation	75
2	Supplies on order	68	5	Quantity to reorder	0
3	Qualified demand	30	6	Physical stock end of day	43

Figure 12 - Day 3 of the simulation on material A [Own source]

On day 3 (shown by figure 12), the initial stock is 37 from the day before and the supplies on order are equal to $34 + 22 + 12 = 68$. The buffer still detects the spike of demand of 24 units in two days, therefore the qualified demand is $6 + 24 = 30$. From that, the net flow equation is calculated at $37 + 68 - 30 = 75$. On day 3, the net flow equation is higher than the top of the yellow zone (63), which means that the purchase team does not need to pass an order of material A, the buffer has enough stock to function (considering all the qualified demand). Hence, the quantity to reorder is 0. At the end of the day, the physical stock is equal to $37 + 12 - 6 = 43$. The physical stock is higher than the top of the red zone (27), which means that it is in the green zone in term of execution buffer. The difference between the planification and the execution buffer will be explained in the next chapter.



1	Physical stock on hand	43	4	Net flow equation	65
2	Supplies on order	56	5	Quantity to reorder	0
3	Qualified demand	35	6	Physical stock end of day	54

Figure 13 - Day 4 of the simulation on material A [Own source]

On day 4, last day of the simulation example (detailed on figure 13) the initial stock is 43 and the supplies on order are equal to $34 + 22 = 56$. The buffer continues to detect the spike of demand of 24 units in one day, so the qualified demand is $11 + 24 = 35$. Therefore, the net flow equation is equal to $43 + 56 - 35 = 65$. The net flow equation is still higher than the top of yellow zone and no replenishment of materiel A need to be done. At the end of the simulation, the physical stock is equal to $43 + 22 - 11 = 54$.

In DDMRP, the historical evolution of the physical stock and the net flow equation can be easily found by looking at the values on the buffer. The result of the 4 days simulation is given in the figure 13, with the history of each day. Because the buffer had the visibility on the demand spike, the net flow equation stayed 2 days in the yellow zone which triggered two orders of replenishment to be able to absorb the variability of the spike without even going into the red zone. Without the visibility the buffer would have been able to deal with the spike without causing a shortage, because it is designed with a red safety zone to ensure a high level of service, but the situation would have been more tensed. That is why DDMRP allows the net flow equation to detect this kind of variability.

What is important to remember, while using the DDMRP method, is that the key indicator of well-being of the buffer is the value of its net flow equation and not its physical stock. Of course, the net flow equation includes the physical stock at the moment, but it also includes the on-going supplies and the spike of demand that presents risks of shortage to the buffer. Hence, it is a more complete representation of wealth of the stock.

Furthermore, the planification order are done in a pull-flow system. It’s the daily demand, added to the detectable spikes that form the qualified demand that will be considered in the net flow equation. This pull-flow part is still true even if the buffer is in “static” mode with its parameter ADU is fixed and does not vary with the fluctuation of the demand (which would cause to increase or decrease the size of its zone during the time),

Here the examples are done by hand, but some software specialized in DDMRP are constructed to compute the buffers levels everyday (for all the protected references of the companies). SAP, the main ERP provider in the world, has recently announced that it will launch its own DDMRP module, compliant with the Demand Driven Institute [9].

5.2.5. Visible and collaborative execution

In planification, the net flow equation is preferred to use when deciding if a new order should be passed or not. But because it is known that in practice, not everything goes like it was planned, DDMRP is also a tool to deal with prioritization and avoid shortages. Indeed, it can trigger an alert on the physical stock when the stock on hand enters the red zone in term of the execution buffer. Hence, the purchase and supply team can know what are the buffers to follow with attention and maybe send a reminder to the supplier or the production team in case of delay in the supplies on-going. In addition, a replenishment delayed or blocked by a quality verification will appear in the net flow equation (therefore the planification buffer can be in the green) but the physical stock will still be in the red.

The execution buffer is close to the planification buffer in DDMRP, but a few changes are to be noted:

- The red zone of execution matches the base of red zone in planification, which is equal to $\mathrm{ADU} * \mathrm{DLT} * \mathrm{LTF}$;
- The yellow zone of execution corresponds to the safety of red zone in planification which is equal to $\mathrm{ADU} * \mathrm{DLT} * \mathrm{LTF} * VF$;
- The green zone of execution matches the yellow zone of planification ($\mathrm{ADU} * \mathrm{DLT}$).

<u>*Example:*</u> The execution buffer of the material A is showed on the figure 14.

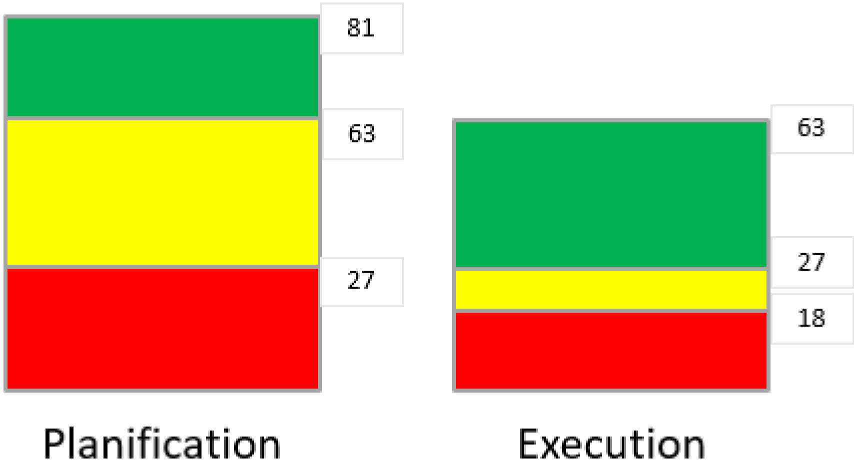


Figure 14 - Buffers are different in execution [Own source]

Hence, in execution, the physical stock is used to prioritize orders and to launch alerts on buffers that could be at risks. At the end of the fifth step the company implementing DDMRP has now a complete tutorial to start positioning its buffers, size them and use the net flow equation to manage its stock and production system.

While the three first steps correspond to the implementation of DDMRP (positioning the buffers, sizing them and adjusting them with factors), the two last steps are the operating parts of the solution (pull the demand while needed, control and prioritize the orders).

5.3. Concrete example of implementation

In this section, some confidential data of a French company are used to highlight what benefits could be obtained by switching to a DDMRP method, hence the name of the company will not be given. The data and results presented in this section are not to be shared without the authorization of the consulting firm CITWELL.

The business case perimeter is a factory of a French company, in charge of the maintenance of transportation equipment. The factory's warehouse contains 3000 components to be used on the equipment, for a total cost of 8M€ of pieces. Before the system's change, the replenishment is done by a Min/Max criterion: when a component's stock goes under the reorder point, a new purchase is launched to the maximal capacity defined. Those points have been arbitrarily chosen and are not modified dynamically.

A DDMRP simulation was done to compare the inventory costs of managing the 3000 components using DDMRP buffers on all the references versus using Min/max criterion. The simulation was created by taking the historical consumption of the last two years. It started with the same physical inventory and let the two methods compute when and how much reorder the quantities. To be coherent with the low visibility of forecasted demand and spike in the company, the DDMRP method was parameterized not to be able to detect the future demand and to only react to the current one.

At the end of the DDMRP simulation, it was observed that the total inventory cost had decrease from 8M€ to 6M€ (-25% in inventory level), which represents a profit in cash of 2M€ and a reduction in the handling costs of 400,000€ per year (with a company possession rate of 20%).

Moreover, the level of service had increased from 95,5% to 97,5% with the DDMRP method, which shows a decrease of component's shortages in the two years of simulation, compared to the historically situation.

On the following example in figure 15, the result of the simulation is showed for one component. The bimodal repartition of stock phenomenon can be seen in the historical curve of stock, with an overstock of the component in the middle of 2017 and a period of shortage during 2018. That can be explained by the three big reorders at the beginning of 2017 to try to anticipate a consumption which seemed to increase. Because the purchase team saw that the stock was at a level too high, they did not anticipate its reorder that led to a shortage in 2018, with a difficulty to reestablish a normal situation.

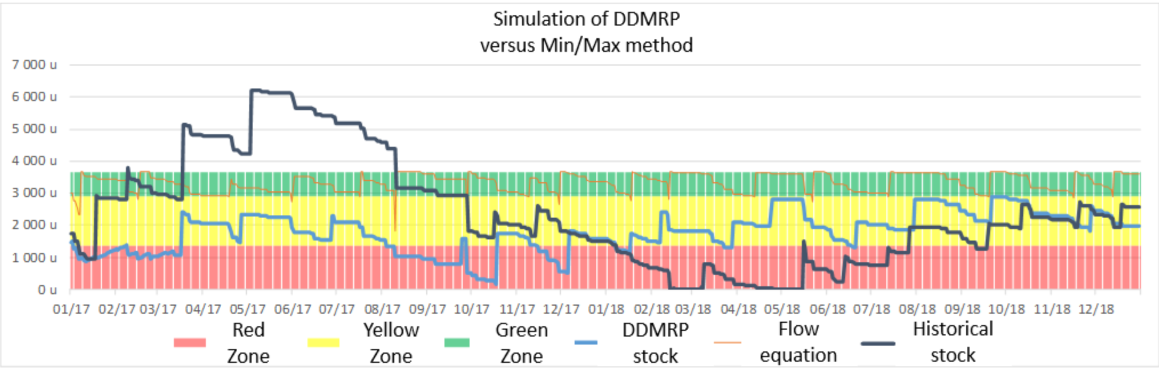


Figure 15 - DDMRP Simulation of a component [10]

On the other hand, the more regular and controlled replenishments called by DDMRP succeed to keep the physical stock to a medium level in the simulation. The net flow equation can be seen oscillating in the green zone while the stock is almost always in the yellow zone (green zone of execution buffer) without any shortage.

This concrete simulation is an example of the results that can be expected in a company choosing to implement the DDMRP method.

5.4. Benefits from the other solutions

According to Ptak and Smith [7], the DDMRP model promises benefits and improvements in the company that implement it. The consulting firm Camelot Management Consultants has shown in a study from 2019 [11] that the companies choosing DDMRP had the following results:

- +13% of service level in average (+54% at the best);
- -22% in lead time in average (-85% at the best);
- -31% of inventory costs in average (-60% at the best).

Those results are aligned with the different papers that will be analyzed in the state of art of this thesis.

Furthermore, DDMRP has shown the ability to refocus the inventory level around the optimal range, while the other solutions had the tendency to oscillate between two extremes: too little stock and too much stock. That issue is known as the "bi-modal repartition of stock" (representation on the figure 16). The DDMRP method helps the purchase and supply team to optimize the level of stock around the optimal range which is not a "zero stock policy" that can cost a lot to be viable for a company.

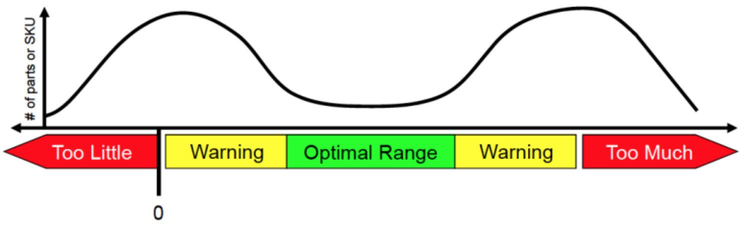


Figure 16 - The bimodal repartition of stock [7]

This optimization of the stock level has two connected benefits:

- The global inventory cost of the company tends to decrease because the DDMRP buffers have less safety stock than the method by point of reorder as they are more agile to pass small replenishment orders defined by the MOQ;
- The level of service increases as the positioning of the buffers along the strategic points of the supply chain allows the company to be more reactive and reduces the risks of shortage.

Another benefit of the DDMRP is its adaptability and ability to acknowledge a variation in the demand without recalculating everything as an MRP system would do. Indeed, the MRP (or MRPII) is going to redo its calculation every time a variability appears in the projection of the demand, modify the quantity to reorder and maybe its reorder due date. While a DDMRP method will firstly verify if it can absorb the spike in the demand (meaning that the net flow equation of the buffer will stay in the green zone), and in that case it will not change the production of replenishment plan. This has the advantage to be more energy-efficient for the computational system and for the team that does not have to redo the checking at every change. Moreover, the DDMRP method can work completely without forecasting or with mix between a fixed ADU and a spike detection for visibility of horizon the buffer has. This flexibility allows DDMRP to be used in systems and companies where the forecasting is not defined enough.

In addition, one of the biggest advantages of DDMRP is its attractiveness and its brief period of adaptation to learn how to handle the solution due to its clear visual management. While the other systems are using numbers and (sometimes) complex KPI to show the current situation to the purchase team, DDMRP has simplified the decision making by defining a tricolor code in planification and in execution. When dealing with a considerable number of references and looking for replenishments to prioritize, DDMRP gives simple and visual rules to apply.

Finally, DDMRP has shown its efficiently in all the steps of supply chain: it can be used for the replenishment of bought raw materials from suppliers, or for production planning and prioritization of the semi-finished products in the factories, or for managing the level of stock of the finished products in the distribution centers. Moreover, no research has proved, for the moment, that the method would not work for a certain type in industry. In fact, the DDMRP method has been implemented in a lot of different sectors: pharmaceutical, electronics, metallurgy, food processing, construction, aerospace …

5.5. Limits and future improvements

Whereas a DDMRP system seems like a particularly suitable alternative to a traditional pull or push flow system, it has to be noted that this new system still has some limits that will have to be dealt with to ensure its possible globalization in the industry.

Firstly, DDMRP is lacking some concrete decision tools for the first three steps of implementation (positioning the buffers, sizing them and evaluating their factors). Indeed, even if criteria have been created to help the transformation team to go through those steps, there is no factual rule to automatize the decision. Hence, each possible position for a buffer must be considered and its factors will be decided on relative rules. In the case of dealing with a lot of references, the implementation time can be important.

In addition, the databases need to be clean with correct input data for the system to work without interferences. That includes having a correct value of lead time for every supplier (or duration of production in the factory). Sometimes, the company also must deal with many constraints that will have to be included in the DDMRP method. If the MOQ is naturally considered in the solution, the suppliers or production team can also impose a fixed cycle of order/production (which means that the buffer has to launch a replenishment order at constant period). Another constraint could be a conditioning multiple batch (to optimize their production and transport). Those added constraints will decrease the maximal efficiency of the method but are frequently inevitable.

Currently, the DDMRP software also have issues when dealing in sectors with products with a lot of BOM (Bill Of Materials) levels (the assembly lines for example). When multiple buffers are positioned at various levels of the BOM, it complexifies the calculations and can lead to erroneous data. But in theory, DDMRP is able to deal with this case and the automatization of the rules for sizing and parameterizing buffers will help the software to manage this complexity in the future.

However, there is one case where DDMRP seems to have trouble giving satisfactory performance results: when evolving in environment with high erraticity of the demand. Indeed, DDMRP has been constructed to be able to absorb the spike of unregular demand without reprocessing everything and to adapt dynamically in the change of the ADU. But this construction requires that an average daily usage can be calculated and corresponds globally to the real demand. If the standard deviation is enormous, the ADU is not representative of the reality and DDMRP will have trouble performing.

Finally, this method does not look life very disruptive at first glance, because it is built from known and usual techniques (MRP, DRP, Lean…). Hence the people that will use it may have trouble to adapt it. Indeed, one facilitating condition for conducting a change in management is to change completely the processes not to give the impression that the new method is "half-new", using also old techniques [12]. Therefore, to make a successful change and to be sure that every key user will accept and adapt to DDMRP, it is important to give a major place to change management in the transformation project.

5.6. The Demand Driven Institute

The Demand Driven Institute was created in 2011 by Carol Ptak and Chad Smith with the mission to diffuse Demand Driven strategies and practices in the industrial community. It gathers all the affiliates, the compliant software and the labelled instructors to help the development of this new strategy. They created some certification labels for demand planner and demand leader and authored papers to analyze and give credibility to this new method [13].

Gradually, they constructed a complete system of Demand Driven strategies call the Demand Driven Adaptive Enterprise Model for every level of the company, from the operational part to the strategic one. In operational, they built the Demand Driven Operational model, in which the DDMRP is included alongside the Demand Driven Execution and the Demand Driven Capacity Scheduling. The three sub-systems allow a company to manage its operations between the planification, the scheduling and the execution.

At mid-level they created the Demand Driven S&OP that makes the link between the operational level of the Demand Driven operating Model (with a relevant range from a few hours to a few weeks) and the corporate level of the Adaptive S&OP system (with a relevant granularity from monthly to annual).

DDS&OP reconciles and configures the Demand Driven Operating Model with the strategic expectations of the business and it also reconciles and configures strategic decisions with the demonstrated capabilities of the existing model. The interactions between the three levels are described in the following graphic, on figure 17, of the Demand Driven Adaptive Enterprise Model.

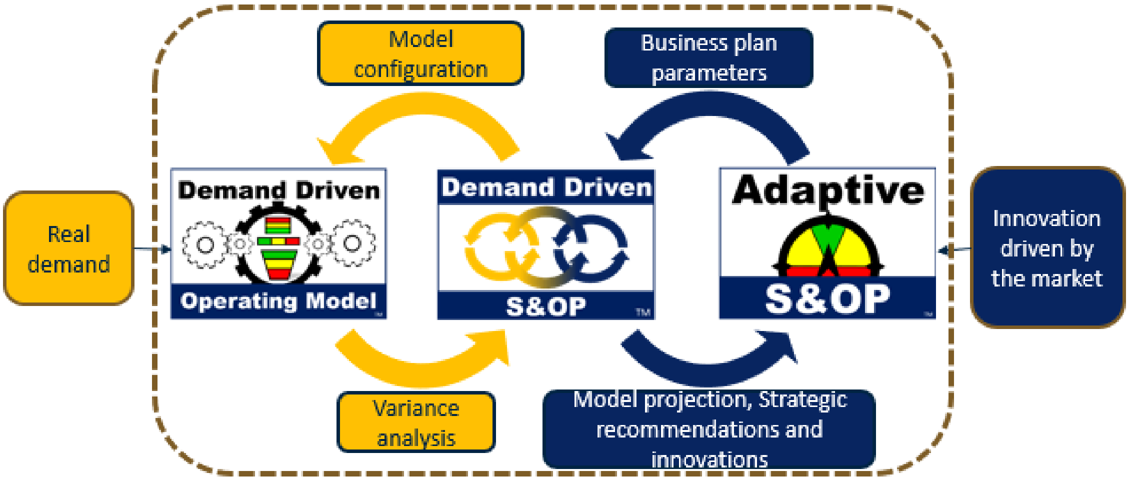


Figure 17 - The Demand Driven Adaptive Enterprise Model [13]

6. The DDMRP from the academic point of view

The goal of this part of the study was to categorize the level of research done on this solution and highlight the results and discussion of the already-existing papers. Therefore, it could be used for others to acknowledge what are the missing documented and studied part of this method. After the research and the flow equation to restrict the search to a few articles, the papers are described and criticized on a methodology point of view.

6.1. Search engines used and methodology

In order to establish the current state of art of the solution, it was chosen to focus the search on three different engines to optimize and cover the scope of existing documentation about DDMRP.

- World of Science;
- SCOPUS;
- FOCUS (Paris Saclay University search Engine).

The equation's search was:

1. Search with the keyword "DDMRP";
2. Filter the results since 2015 (as it is a quite recent solution);
3. Select peer-reviewed article (to exclude all conferencing papers and newspapers);
4. Remove the duplicates between the three engines;
5. Exclude non related subject after abstract reading.

As it is a solution developed in consulting firms, they are a lot of grey papers written about it in specialized magazines of supply chain and logistics. However, it was decided to only keep the peer-reviewed articles from academical origins to reduce the bias effect from the fact that the writers of those grey papers are often also trying to sell the DDMRP solution to companies and that might modify their way of presenting the solution.

6.2. Results

After using the equation in the three search engines, the results went from originally 83 articles to the 5 articles that are used and analyzed for this master thesis. The search is summarized in the following graphic of figure 18:

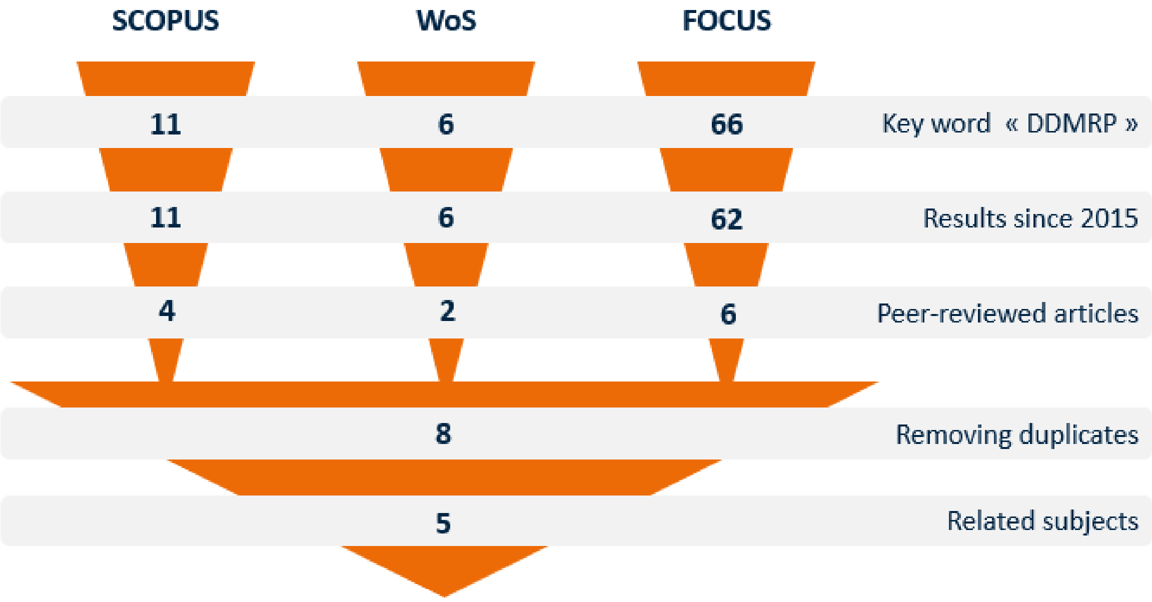


Figure 18 - Flow equation of bibliography [Own source]

Those five articles can be found in the following table in figure 19 and are now going to be described and commented.

Titre	Créateur	Année
An empirical comparison of MRPII and Demand-Driven MRP	Miclo et al.	2016
Compréhension du DDMRP et de son adoption: premiers éléments empiriques	Bahu et al.	2019
Demand Driven MRP: assessment of a new approach to materials management	Miclo et al.	2019
Effective production control in an automotive industry: MRP vs. demand-driven MRP	Shofa et Widyarto	2017
Material management without forecasting: From MRP to demand driven MRP	Kortabarria et al.	2018

Figure 19 - Summary of the 5 articles found [Own source]

6.3. Study of the articles

The first step was to compare the keywords announced in the abstract of each paper (except the paper from Shofa [14] that did not have keywords). The keywords used are similar and deals with:

- Types of system (DDMRP, Lean, Kanban, MRP, JIT manufacturing);
- Production objectives (visibility, production control, inventory management/level);
- Demand variability (uncertainty, forecasting, variability management).

The articles are described and commented in the next parts of the paper.

6.3.1. An empirical comparison of MRPII and Demand-Driven MRP (2016)

Miclo et al. [15] evaluate and measure, on a concrete example, the differences between MRPII (Manufacturing Resources Planning) and DDMRP (Demand Driven MRP). The paper compares two key performance indicators: OTD (On Time Delivery: ratio of orders delivered on time divided by the total number of orders) and WC (Working Capital: indicator of a company's liquidity, measured by the difference between its currents assets – cash, inventories… - and its current liabilities).

To compare those two indicators, it uses a study case (Kanban serious game, from the CIPE: Centre International de la Pédagogie d'Entreprise [16]) that gives data of a company producing reducers (6 finished goods and a part) for 6 weeks. With those data, they did a DES (Discrete Events Simulation) test on a computer to capture the reactions of the two Manufacturing Planning and Control systems.

Seven simulations were made in different scenarios to compare the KPIs: with and without spikes, variability, demand visibility, seasonality… The goal was to verify four hypotheses: DDMRP has better performances regarding variabilities, DDMRP counteracts more efficiently those variabilities, DDMRP reduces the risks of shortage on spike demand and DDMRP keeps the level of stock in low-risk zones.

At the end of the simulations, the results showed that DDMRP is able to get a lower WC (-10% in average) at the same level of OTD, with less nervousness in the reaction to spikes and variability.

In one scenario, DDMRP can't beat the MRPII system because it reacts too weakly to a huge spike without anticipation in a high seasonality period. In the next scenario, the spike is anticipated, which allows DDMRP to get better results. Hence, the study shows that DDMRP is mostly efficient with demand anticipation.

The weight of this article must be mitigated by the fact that only one study case was used to compare the two solutions (not even a business case). The article is an empirical comparison and its results cannot be utilized globally without precaution.

6.3.2. Compréhension du DDMRP et de son adoption : premiers éléments empiriques (2019)

In this article, Bahu, Bironneau & Hovelaque [2] are trying to understand what is DDMRP and pinpoint why companies choose to implement DDMRP through 30 business cases.

The study first describes the five steps to implement DDMRP and conclude that it is a system that gives a tool able to pilot the stock day to day with simple indicators to know what to replenish and what are the stocks at risks.

A flow equation for a literature review was done to pinpoint the lack of academical studies of the reasons for companies to implement the solution. That explains their choices to focus on that question.

To understand the enthusiasm for DDMRP in the companies, they went through 26 business cases. The cases were collected from companies of varied sizes (from small and medium-sized enterprise to big groups), in different sectors (pharmaceutical, electronics, metallurgy, food processing, construction, aerospace …) and from different countries (France, Columbia, United States, Great Britain, Ukraine, Spain…). They also noted in which function the DDMRP solution was implemented (procurement, production or distribution).

In addition, they collected data of 4 other companies with DDMRP solution implemented through direct interviews with managers.

As an introduction to the results, they firstly state that they are aware that their sample has multiple variability criteria (size, sector, function, country). But, as there is no study on how that could impact the results on DDMRP and as they did not see differences, they chose to ignore those differences in the criteria and assume that the solution is functional for every situation.

The authors give three reasons for companies to choose DDMRP after the studies and interviews of the 30 companies:

- It is naturally derived from the theory of constraints;
- It allows companies to get a global diminution of their level of stocks;
- It proposes simple and visual tools, easy to manage and perfect for agile decision.

On the other hand, they underline the fact that without clear rules and algorithm to apply directly. The settings of the buffers are mostly done by practice and test. Hence, it might be complicated to apply quickly on a large scale: some tools are lacking to do a robust implementation and a clear decision making.

This is a good study in term of quality because the methodology is clear and well defined. They clearly explain how and why they construct their flow equation. However, they state that they don't have a conflict of interest for that study but they firstly thanks Laurent Vigouroux, the CEO of one of the biggest pure player software for DDMRP in France [17] as the person helping them to get the contacts for the business cases. So, he might has only showed them what he wanted them to see.

6.3.3. Demand Driven MRP: assessment of a new approach to materials management (2018)

This article can be seen as an extension of Miclo thesis from 2016 [15], but the authors are now doing a comparison of, in the meantime, MRPII, Kanban and DDMRP through simulated events [4].

Through a history of Manufacturing Planning and Control systems, they describe how and in what context the DDMRP solution was implemented and summarize the unique features Ptak and Smith constructed for this stock management method. Before going into the simulation, they also present a list of "success stories" of DDMRP implementation in company, extract from the Demand Driven Institute website [13].

In this paper, the authors take the time to describe with precision the method of a discrete event computer simulation, justifying its utility and usefulness by quoting articles who studied this technique and its application in manufacturing and operations management. They present the four sequential steps:

- The development of the simulation model (what is the settings used);
- The experimental design (provides the structure used for the simulation and identifies the independent variables of interest);
- The generation of data;
- The analysis of data through statistical tools.

After this presentation, they developed the four steps in this case simulation, using the CIPE Kanban game [16].

As a conclusion, they recognize that their results do not show the unconditional dominance of DDMRP over MRPII or Kanban, as the study is only made on a limited numbers of environment conditions and on only one study case. Nonetheless, on the tested perimeters, DDMRP shows interesting results because it gives superior results both in low and high variability conditions. Mostly when the variability is low, where its mixed origin between MRP and Lean technique allows him to be very performant, but the results still are good in high variability environment.

The well-described methodology, with results analyzed with statistical tools (Anova method, pairwise comparison…) and the pertinency of the authors to criticize their paper categorize this article as a high-quality research one and give him more authority and its conclusions.

6.3.4. Effective production control in an automotive industry: MRP vs. demand-driven MRP (2017)

This article, from Shofa and Widyarto [14] evaluates the performance of DDMRP versus MRP in term of level of stock and lead times through a business case simulation.

It is interesting to pinpoints that the authors are from the University Serang Raya, Indonesia, which means that the interest for the solution is worldwide and also studied in Asia, not only in Europe and in the USA.

To answer their problematic and evaluate the differences of performance between DDMRP and MRP, they chose to use a 4 weeks simulation on 3 articles of an automotive company in Indonesia (from March to April 2015). The forecasts were given by the company and variations (not described) were applied to form a stochastic environment.

At the end of the simulation, two variables were compared, lead times and level of stocks. The lead times are compared as DDMRP allows companies to reduce them by positioning buffers through the supply chain (as it will be explained later in this master thesis) which will decouple the unprotected chain. For the level of stocks, the authors chose to compare its position through five possible categories (“Too little”, “Red”, “Yellow”, “Green” and “Too much”).

At the end of their paper, they state that, with their simulation, DDMRP reduces the lead time of 94%, from 52 to 3 days (this makes sense because MRP has no direct goal to reduce it).

They also obtain that DDMRP can shift the level of stock in the effective parts of it while MRP conduces to a lot of stock in the ineffective level of stocks (too much and/or too little). On the other side, positioning buffers creates intermediate stocks in the buffers and that must be considered in the inventory costs.

Compared to the other articles, this study and simulation is done on a real company forecast data, which could give more credits to its results, but lack of auto-criticize and moderation on their statements are lowering the quality of the paper.

6.3.5. Material management without forecasting: from MRP to demand driven MRP (2018)

This article, from Kortabarria et al. [3] has the objective to show the complete simulation and results of the implementation of a DDMRP solution in a company, to highlight which improvements could be obtained with this solution.

After a brief description of the origin and the explanation of the DDMRP system, they explain step by step the choices and decisions made to implement the solution, leading to a series of comparison between before and after the new manufacturing planning and control systems.

For this simulation, they use a case study of a Spanish company leader in its sector in Spain and selling goods in more than 50 countries. The anonymity of the company has been preserved for the publication of the study. Suppliers are mostly located in China with an average lead time of 3,5 months for the +500 references analyzed. The company needs to serve its customers with a maximal delay of 2 days. Before the new stock management system, the mains issues are:

- A high level of stock on hand (due to the localization of the suppliers);
- A purchase order planning updated only one time per month with an isolated responsible for the purchase orders (the rest of the team were lacking the knowledge);
- A lack of visibility for replenishment decisions.

From this well-described initial situation, the authors explain the choices that were made to implement DDMRP and what where the results.

After implementation, the results showed that the DDMRP system helped the company to increase the visibility in its supply chain and the visual management of the solution facilitated the decision making on replenishments and management of the families of products. The inventory level was reduced by more than 50% while maintaining the same level of service. In addition, the average daily uses of the references increase of about 8%, which means that the stock turnover increased too.

In conclusion of their study, they highlight the efficiency of DDMRP to reduce the uncertainty of demand by piloting without using the forecast as the only input and its ability to reduce the global level of stock of a company. As the authors stated at the end of their paper: “Efficient Operations and supply chain management is key to achieving a sustainable competitive edge” [3] and DDMRP appears to be constructed to successfully be efficient on the VUCA environment that was described.

6.4. Conclusion of the search

As it was expected in the methodology, including peer-reviewed articles only has lowered the number of articles available on the subject to only five. The other articles - that can still be useful to be trained on how the solution works and how to implement it – will not be quoted in this work.

Some other thesis could be found via Google Scholar, but it was decided to limit the scope of the search to the first three engines as they were the engines used in the two universities (ETSEIB and CentraleSupélec) supervising the master thesis.

The study of the five articles has shown that most of the papers on DDMRP deal with simulated applications of the solution. This master thesis takes those results into account to highlight the presentation of the Manufacturing Planning and Control system.

7. Implementation analysis

The goal of this section is to evaluate the environment impact and the theorical workload and budget associated to the implementation of a DDMRP method in a company.

7.1. Environmental impact

While DDMRP does not directly influence the environmental footprint of a company, its implementation can be included in a broader effort to minimize the CO2 production and the gas consumption. Indeed, a better stock management is going to influence two factors:

- The global level of stock: by decreasing the level of stock, the global surface of storage can be redesign and the maintenance and energy costs will decrease;
- The decrease of high-cost shortages: by improving the level of service with less shortages on the materials, the company will not have to pass express reorder by plane that are extremely pollutant for the environment.

Nonetheless, DDMRP tends to increase the numbers of reorders by decreasing the lot size. That can negatively influence the environmental footprint of a supplier by increasing the number of travels and lowering the optimization of the travel variable cost.

Moreover, the increase of efficiency in the production scheduling will imply a smoothing of the production lines, which means capacity better adjusted with less spikes. As variability is always more expensive than regularity (because in case of possible variability, the worst-case scenario must be chosen for capacity and energy sizing), DDMRP will improve the environmental impact of the company.

On the technological side, DDMRP will replace MRP, which calculation computing are more energy-costly, with the same number of computers to function. Hence, DDMRP will not worsen the environment footprint and can even improve it where the databases are computing.

7.2. Budget and workload projection

To evaluate the budget and workload associated, this section of the master thesis was built like a commercial proposition of implementation from a consulting firm to a company. Hence, three types of charges were included:

- The fees from the consulting firm to support the implementation. There are three types of profiles that are required in that project: a DDMRP expert which will lead the formations and bring its experiences when needed, a project leader to manage the planning, supervise the budget and lead the change and a consultant to implement the DDMRP method in the company;
- The internal workload of the company to conduct the change: the considered teams are the supply and purchases ones, the project leader in intern which is responsible of the project development and the sponsorship of the project, usually the direction;
- The costs associated to the installation and maintenance of a specialized software.

The estimated budget and workload are given for a middle-sized company, working with around 3000 references with low level of BOM. In that case of implementation, the project is usually divided in three phases with different goals in each:

- Phase 1 : First steps ;
- Phase 2 : Environment modeling;
- Phase 3 : Pilot and follow-up.

7.2.1. First steps of a DDMRP implementation project

The mains objective of this first phase is to understand the actual processes, delimit the scope of the project and propagate the DDMRP philosophy in the company. To achieve those goals, the consulting firm will do the project's framing, a diagnostic of the current situation and will perform some formations.

A project's framing is composed of interviews of the leadership and the impacted teams to understand for each one their constraints, their fears and their expectations. Then the scope of the implementation is discussed (is it on one factory for the moment ? on all the distribution channels ?...). After that a diagnostic can be realized to collect field data: what is the global level of stock, what are the known variables from the suppliers/production team (MOQ, lead time…). The diagnostic also includes a value stream mapping of the different flows to understand the actual processes of the company. After gathering the data, the consulting firm can compute a first estimation of what could be achieved by implementing DDMRP by using its own benchmarks.

In the meantime, it is important to increase the level of conviction of the utility of this new method to ease the change management and imply all the impacted actors in the project. For that, some educational games are firstly done to understand the general concept of DDMRP. One of the most famous of these games is the DD BRIX [18], created by Laurent Vigouroux, it's a derivate from a beer game and is played with Lego bricks that puts the participant in a production and distribution of a small tower of Lego bricks. After that, it is usual for the core users of the DDMRP method (purchase and planification team) to pass the first level of certification delivered by the Demand Driven Institute: the Demand Driven Planner (DDP) [19] which is a formation done in two days that gives a complete view of the DDMRP method for implementing and using it.

The estimated internal workload and the fees associated to the consulting firm are shown in the following table in figure 20.

	Consulting firm			Internal teams			
	DDMRP Expert	Project leader	Consultant	Supply team	Purchase team	Project leader	Project sponsor
Framing		5 days	1 days	1 days		3 days	2 days
Diagnostic		4 days	20 days	3 days	2 days	5 days	3 days
Formations	8 days	1 days		5 days	5 days	5 days	
Daily fees	2 000 €	1 500 €	1 000 €				
Total	16 000 €	15 000 €	21 000 €	52 000 €			

Figure 20 - Phase 1 – Estimated workload and consulting fees [Own source]

7.2.2. Environment modeling and flows conception

This second phase has for objectives to conceive the operating model that is going to be built around DDMRP and to define the buffers parameters.

Implementing DDMRP is the occasion to do a review of planning and execution processes around the buffers. Even if the Demand Driven Material Requirements Planning method is not disruptive and does not require an important change in the processes, it is important to verify that DDMRP will function totally and adapt the processes otherwise. This must be done for physical flows and for information flows, as the DDMRP chosen software has to be linked with the other databases of the company (a Business Intelligence, an Advanced Planning and Scheduling system, a Transportation Management system…). Hence, all the flows are reviewed and redesigned and the company's constraints and specification are included.

It is usual to launch the project on a pilot, to verify the good functionality of DDMRP on the systems and verify the ability of the impacted teams to manage the change. The pilot is defined on a smaller scope of the project perimeter, with references representative of the company's diversity, that will be managed with DDMRP buffers. For those references, all the sizing parameters must be found. For internal production, it is relatively easy to gather all the variables (MOQ, lead time, product specificity…), while it can be harder for raw material that are bought to suppliers, because the suppliers can be reluctant to be challenged on their announced lead time. Depending on the environment it is also the occasion to add some demand adjustment factor to get the buffers as accurate as possible.

At the end of the phase, the company has the pilot ready to be integrated in the chosen software solution for the launch. The estimated workload and the fees for the consulting presence is shown on the following table in figure 21.

	Consulting firm			Internal teams			
	DDMRP Expert	Project leader	Consultant	Supply team	Purchase team	Project leader	Project sponsor
Processes conception	3 days	10 days	15 days	5 days	3 days	10 days	2 days
Suppliers information		1 days	8 days	2 days	4 days	5 days	
Pilot buffers sizing		2 days	10 days	3 days	1 days	8 days	

Daily fees	2 000 €	1 500 €	1 000 €	
Total	6 000 €	19 500 €	33 000 €	58 500 €

Figure 21 - Phase 2 - Estimated workload and consulting fees [Own source]

7.2.3. Launching the pilot and follow-up

When the buffers for the pilot have been correctly sized with the company's data and the processes have been verified and redesigned, the next step is to integrate a compliant DDMRP software. There are around 20 software that have been approved by the Demand Driven Institute [20], some of them are pure-players entirely designed for Demand Driven MRP, others are extension modules of ERP systems. The software will have to be able to exchange with the other information system of the company to be purely efficient. When the selection is done, the specific coding for interfacing begins and, in the meantime, the core team users are trained to the DDMRP tool.

Once everything has been checked and all the lights are green, a last steering committee gives the go-live for the pilot: DDMRP starts to be used for the specified references. At the beginning, it is not unusual for buffers to be resized after a few periods of utilization because a specific constraint had not been considered and because it is easier to calibrate the lead time, variability and demand adjustment factors while being live. Hence, the efforts are focused on the monitoring of the activity to ensure an equivalent level of service than before the implementation during the adaptation. The internal workload and the fees from the consulting group are resumed in the table at the end of the section.

After a few times, depending on the sector's activity, the operational results can be computed (lead time, level of service, level of stock, quality of work life for users…) and compared to the previous KPIs before the launch. Then, the company has to decide a GO or NO GO on deployment or extension of the DDMRP perimeter, depending on the simulated Return of Investment of the project, calculated with the pilot results.

If they chose a GO to deploy the DDMRP on a broader scale, being satisfied of the good results the first implementation has shown, they can be accompanied by the consulting firm to continue the buffers sizing and processes adjustments of they can chose to pass other DDMRP certifications and training, to internalize the project.

	Consulting firm			Internal teams			
	DDMRP Expert	Project leader	Consultant	Supply team	Purchase team	Project leader	Project sponsor
Interfacing software	2 days	3 days		1 days		3 days	
Go live preparation	4 days	5 days	8 days	1 days	1 days	5 days	3 days
Follow-up and adjustments		4 days	30 days	8 days	1 days	15 days	

Daily fees	2 000 €	1 500 €	1 000 €	
Total	12 000 €	18 000 €	38 000 €	68 000 €

Figure 22 - Phase 3 - Estimated workload and consulting fees [Own source]

In addition of the detailed costs of figure 22, for this project, the costs from the software need to be considered. They can be evaluated to 30 000€ for the buying of the software and the intervention of their specialists for the specific development. After that, the company will have to pay a recurrent cost of 3 000€ per month for licenses of the DDMRP tool.

7.2.4. Summary of the budget and workload associated

On the following table in figure 23, the consulting firm costs are estimated for the all project duration and the internal workload associated. Considering the additional 30k€ to buy the software, the initial investment is around 200 000€.

	Consulting firm			Internal teams			
	DDMRP Expert	Project leader	Consultant	Supply team	Purchase team	Project leader	Project sponsor
Phase 1	8 days	10 days	21 days	9 days	7 days	13 days	5 days
Phase 2	3 days	13 days	33 days	10 days	8 days	23 days	2 days
Phase 3	6 days	12 days	38 days	10 days	2 days	23 days	3 days

Daily fees	2 000 €	1 500 €	1 000 €	
Total	34 000 €	52 500 €	92 000 €	178 500 €

Figure 23 - Project estimated costs [Own source]

In opposition of this investment, the expected results of the implementation of a DDMRP solution can be used to define the return of investment that could be achieved by this project. Considering only the improvement of the level of stock, if a company had an initial total stock of 10M€, with a possession rate at 10% and that DDMRP allows the supply teams to decrease that stock of 20%, it will lower the annual possession cost of 200 000€, as shown in figure 24.

	Before	After
Total level of stock	10 000 000 €	8 000 000 €
Annual possession cost	1 000 000 €	800 000 €

Figure 24 - Project decrease of the stock level [Own source]

Hence, after implementation and in steady state, the return of investment of the project should be around two years (because the benefits of possession are not directly obtained, the return of investment is higher than the one year calculated). Moreover, the other profits are here not computed: increase in the level of service, shortage's decrease…

Finally, to achieve the project, it is important to allocate the necessary time for implementation. The internal workload is not negligible for the teams to appropriate DDMRP and understand its utility, which is important in change management. In addition, the follow-up after the launch of the pilot is important to adjust what was conceived before. Because DDMRP is a try and correct method that, for the moment does not have clear processes on the evaluation of the factors.

Therefore, it can take around six to nine months for the three phases of the project (and more, if the deployment continues after that). A proposition of global project planning is available in the figure 25.

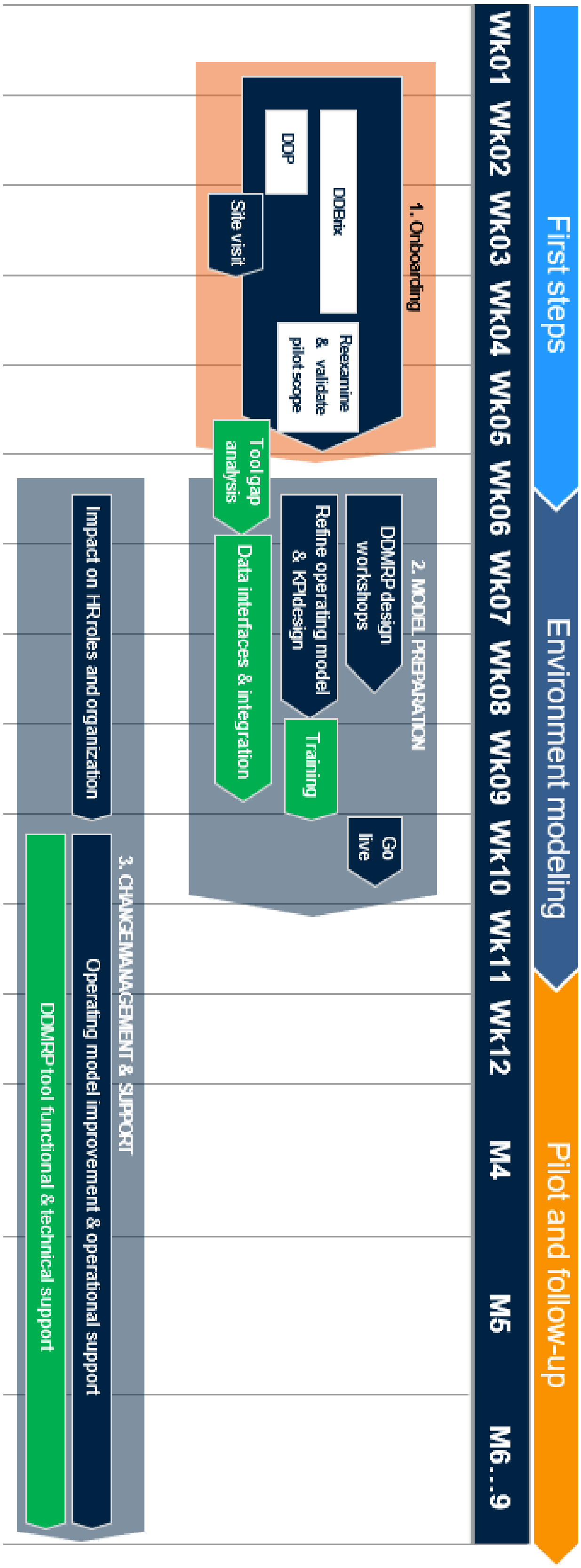


Figure 25 - Project global planning [21]

Conclusion

DDMRP has the potential to become a standard in the supply chain industry for stock management and master production scheduling [22]. It has the ability to refocus the decision making by making it visual and coherent with the real demand. DDMRP is structured around decoupling points to control the stock all across the supply chain. It can produce automatic reports on orders to launch and on alerts to control. Therefore, it is a multilevel and multitasking tool that can replace MRPII and Lean manufacturing in the companies. As a matter of fact, the interest in this method is growing and more and more companies are eager to try this new solution [23].

This interest is based on the particularly good results which derive from the implementation of a DDMRP system: a global diminution of the inventory level, an increase in the service level, a reduction in the lead time through decoupling points, a visual help for prioritizing orders and scheduling production… Moreover, the method seems to be performing for all type of industry, at every level of the supply chain, from the raw material purchased from the suppliers to the finished goods in the distribution centers.

As the method is quite recent, there are still some lever of improvement to be developed and formalized in the solution: more specific and clear rules to position the buffers and evaluate the factors and how can DDMRP be adapted in high erraticity demand environment. Nonetheless, the method is carried and developed by a private institute, the Demand Driven Institute, that ensures its improvement and its knowledge transfer, while creating a broader system around the philosophy “Demand Driven”: the Demand Driven Adaptive Enterprise.

On the academic side, the scientific community starts catching up on the solution, by publishing an increasing number of white papers on the subject, proof that the method has not only a potential but a good future to come.

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